Welcome to the 50th Anniversary of **Exoplanet** Exploration

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1940s-1980s: First Glimmers

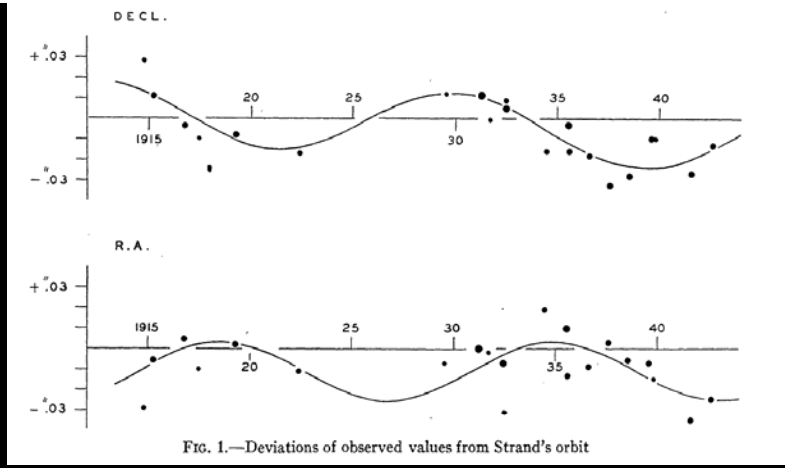


FIG. 1.—Deviations of observed values from Strand's orbit

Van de Kamp, Holmberg (1943)

- 10 M_{jup} astrometric planets come and go

Otto Struve (1952)

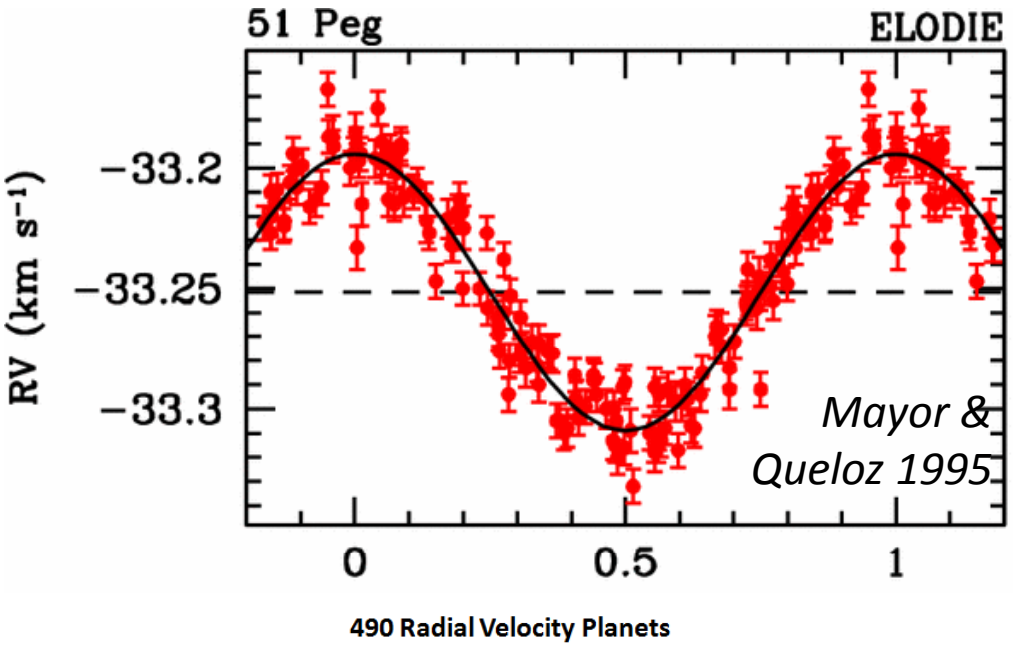
- "One of the burning questions of astronomy deals with the frequency of planet-like bodies in the galaxy which belong to stars other than the Sun…**How shall we proceed to find them**?"
- **Imaging** –"quite limited in scope"
- **Radial Velocity**--- "It is not unreasonable that a planet might exist a distance of 1/50 AU… causing the observed radial velocity of the star to oscillate with a range of 0.2 km/s---a quantity that might be just detectable."
- **Transits**---"There would of course be eclipses...the loss of light in stellar magnitudes is about 0.02. This too should be ascertainable by modern photoelectric methods."

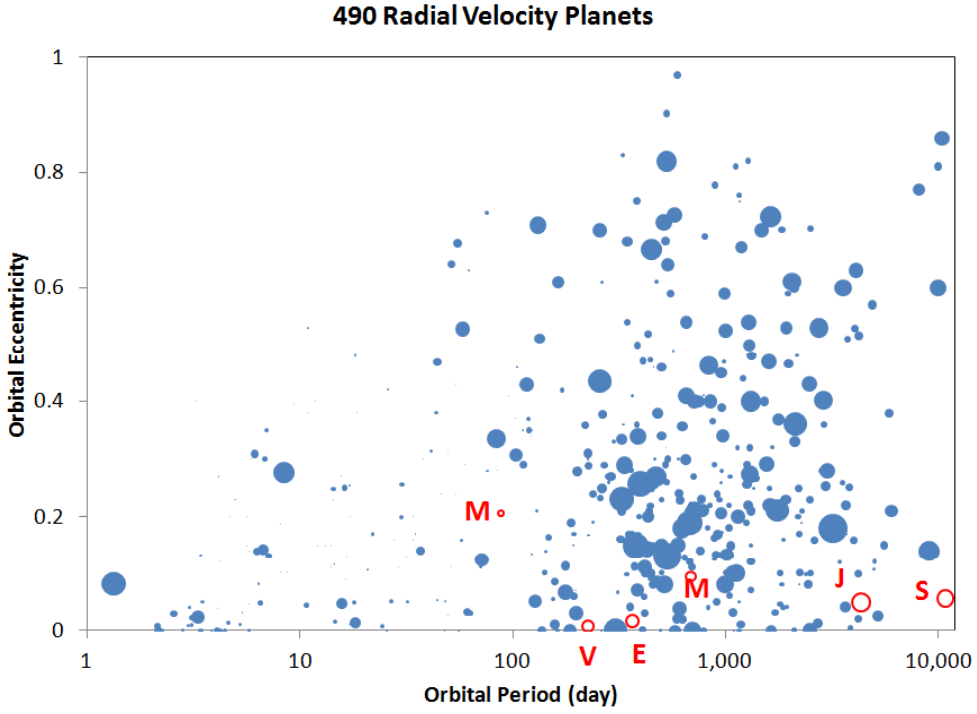
Bruce Campbell and Gordon Walker (1988)

- "Seven stars show small, but statistically significant, long-term trends in the relative velocities….Companions of about 1-9 Jupiter masses are inferred."

Latham et al 1989

- *"The unseen companion of HD114762 - A probable brown dwarf"*

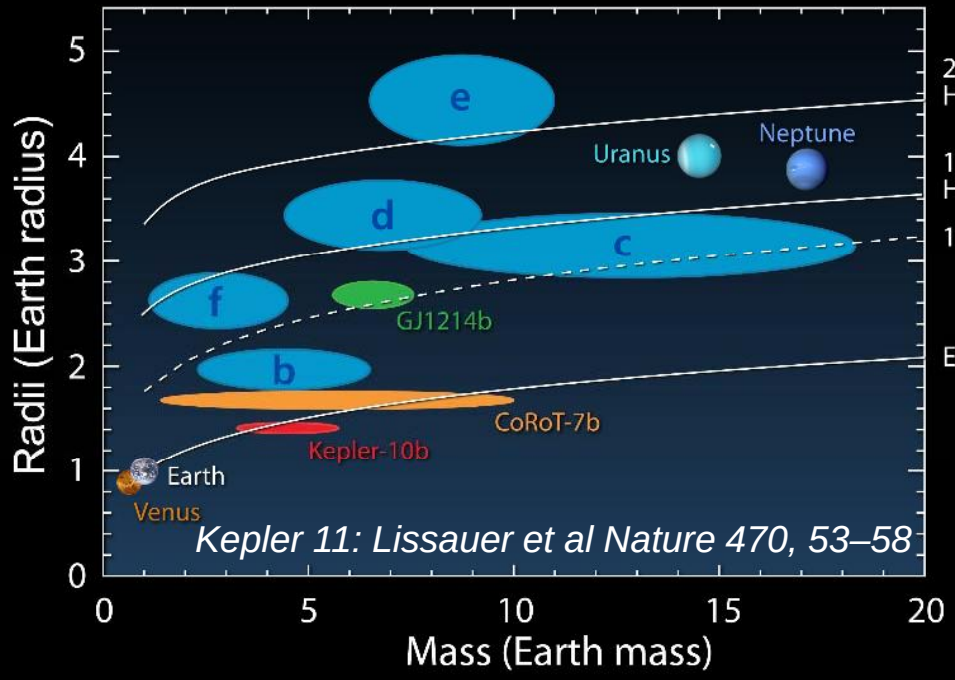




1995-2005: The Floodgates Open

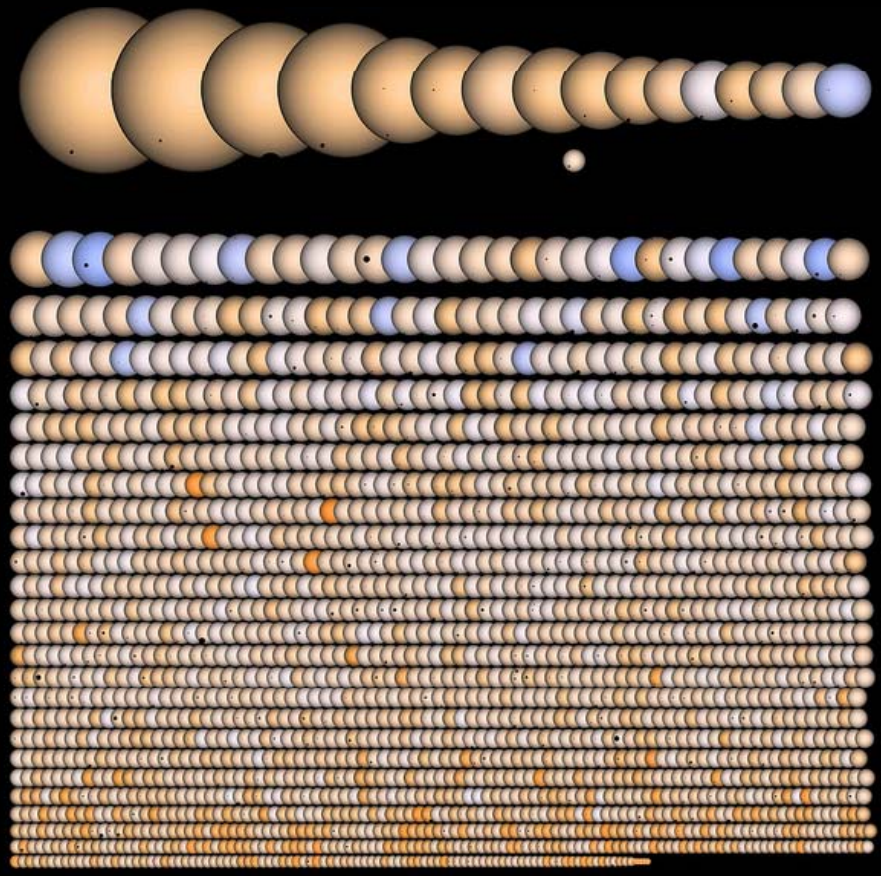
- ***<u>1995:</u> "Annus Mirabilis:" 0.5 M_{Jup} companion in a 4.2 day (!) orbit around 51 Peg***
- Origins: *"Advanced telescope searches for Earth-like planets and habitable environments around other stars."*
- 500 RV planets (NASA/Keck) reveal exoplanet architecture

2005-2015: The Decade of Transits



Kepler 11: Lissauer et al Nature 470, 53–58

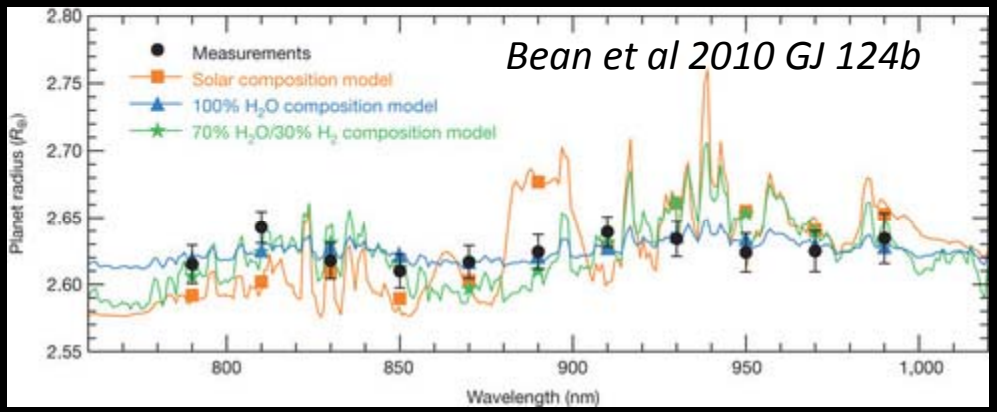
- First Ground based transits (2004)
- NASA's Kepler finds >2,000 candidates

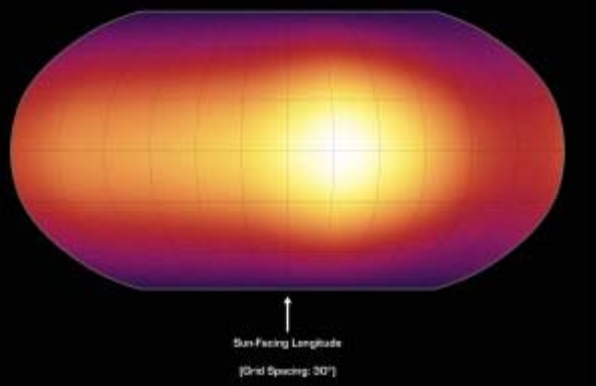


2005-2015: Characterizing Giant Planets

On the subject of stars … We shall never be able by any means to study their chemical composition. *--- August Comte, 1835*

- Spitzer, HST, ground telescopes probe atmospheric composition (H_2O, CH_4, CO_2), vertical structure & weather <u>of planets</u>

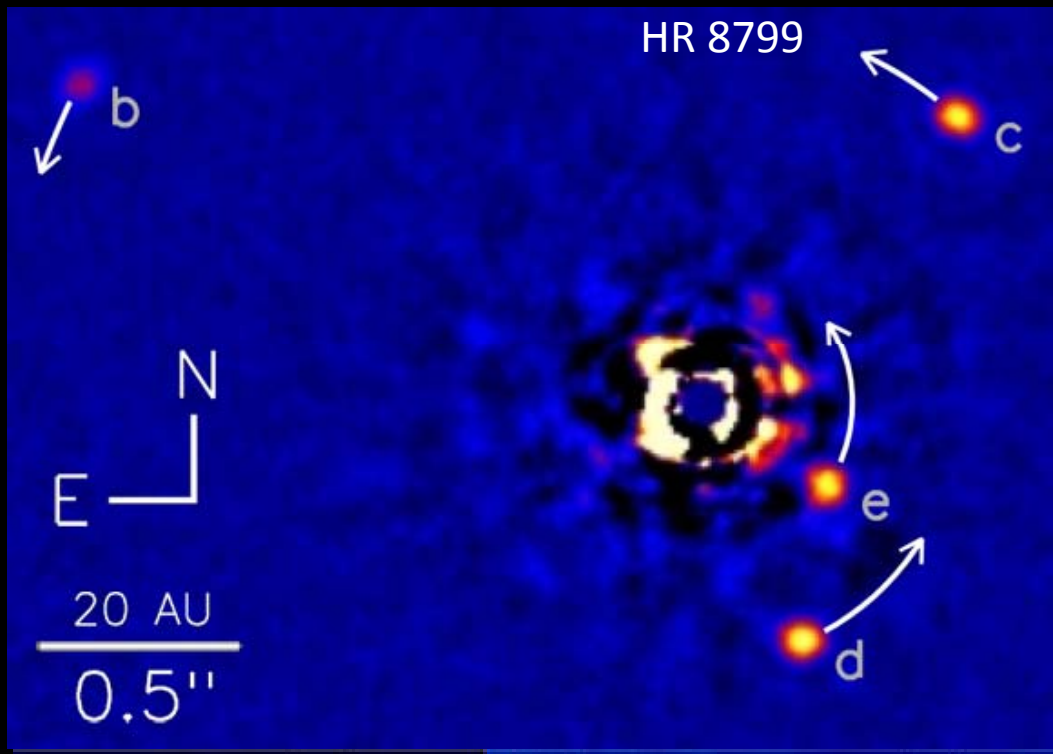


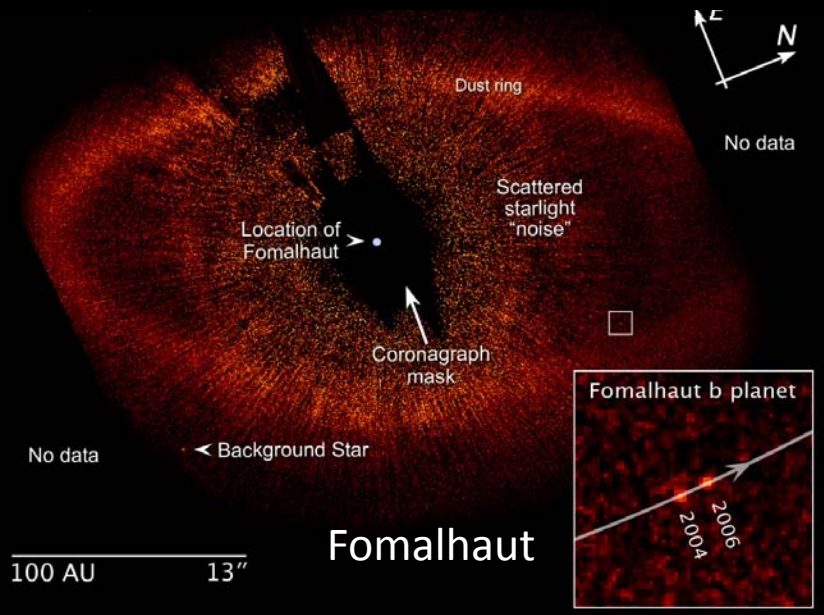


- NASA Planetary & Astrophysics jointly pick ***both*** **TESS and FINESSE Explorers** to find 1,000s of planets transiting bright stars (~30 of Habitable Zone Earths) and to make atlas of 100s of ice/gas giant spectra

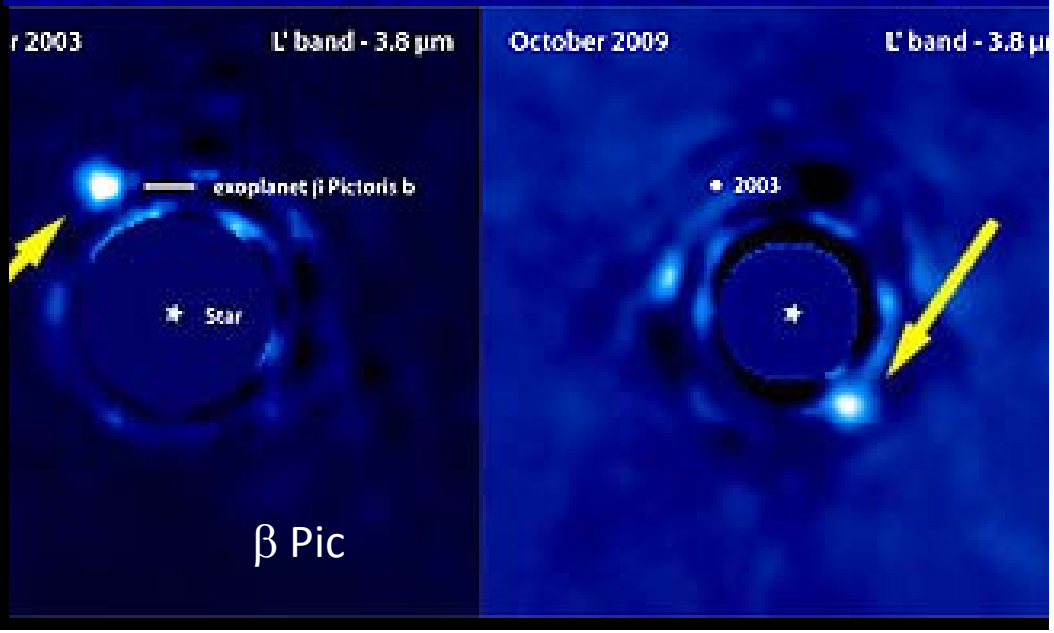
2005-2015: Imaging Planets

Young Jupiters on large orbits from space and ground with Extreme Adaptive Optics on 5-10 (30) m telescopes





Fomalhaut

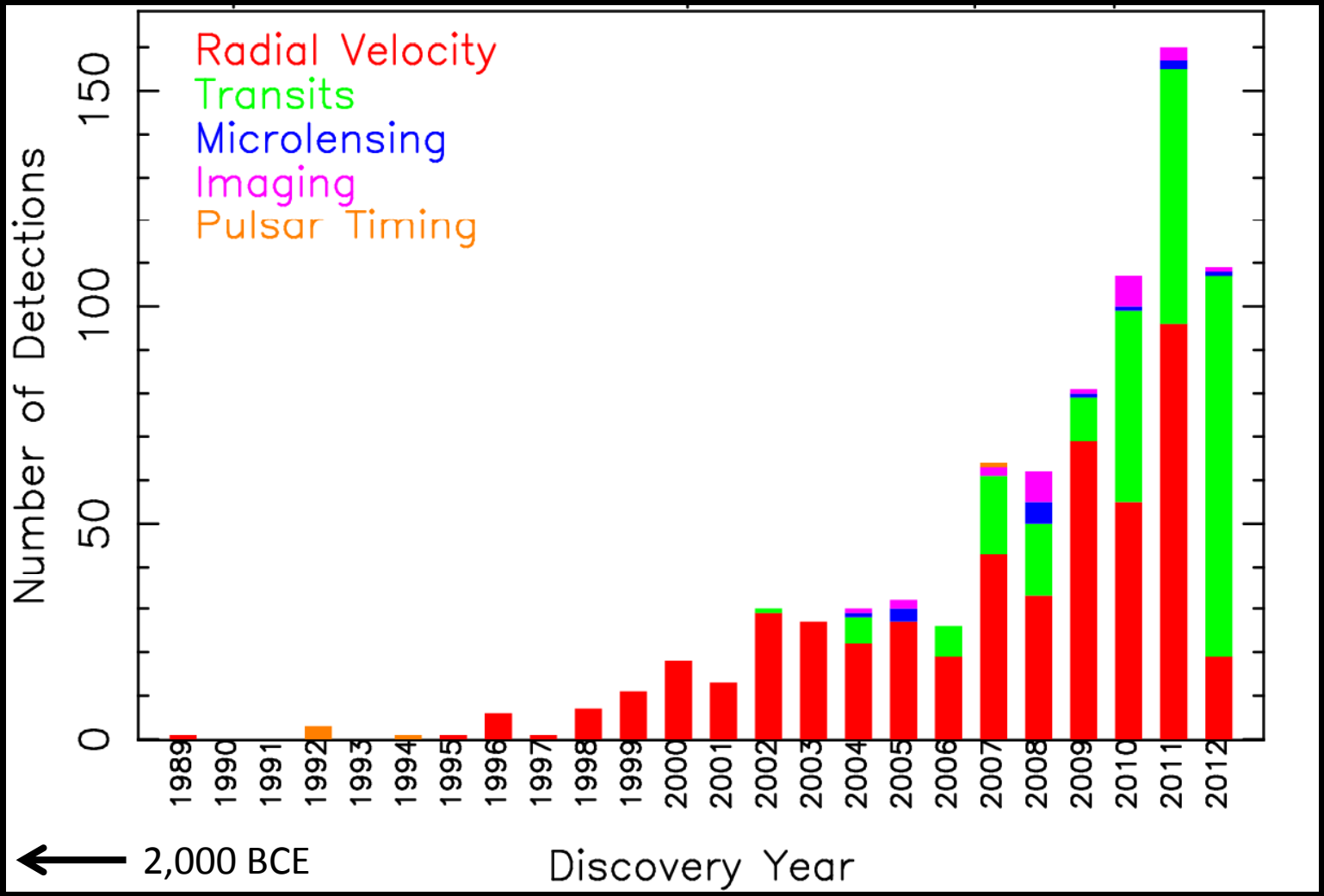


β Pic

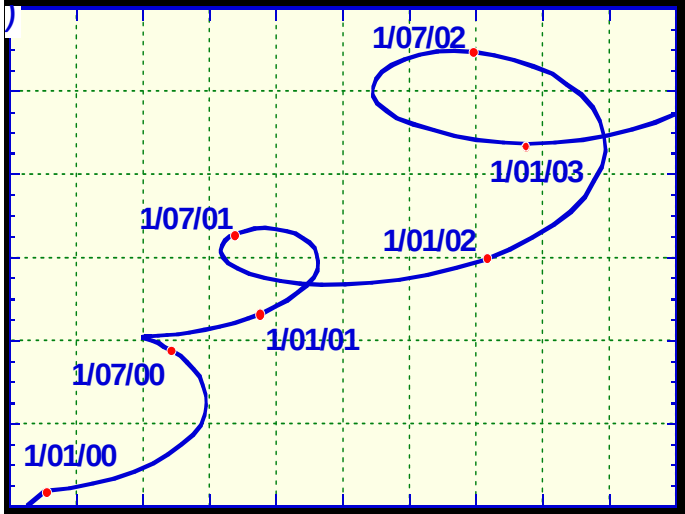
33 Years Ago on Oct 26, 2012:

~~797~~ 798 Planets Around ~~629~~ 630 Stars

+ 2,320 Kepler Planetary Candidates

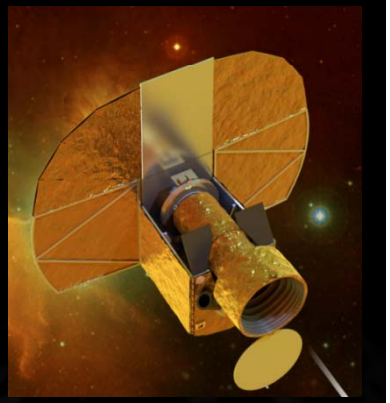


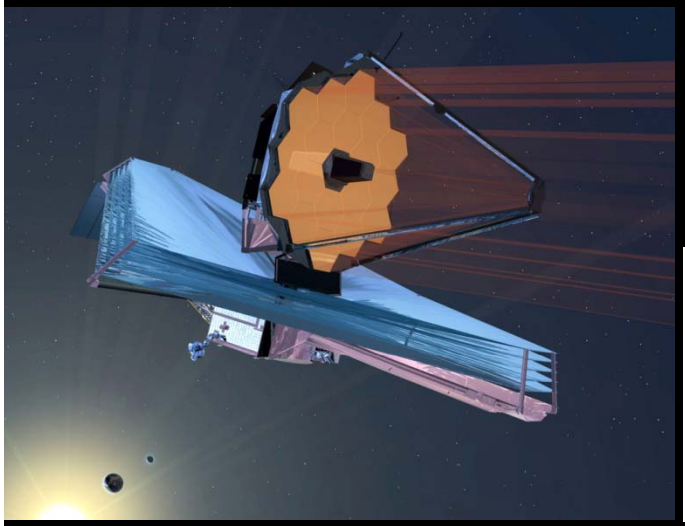
2015-2025: Census Taking, Images and Transits from Space



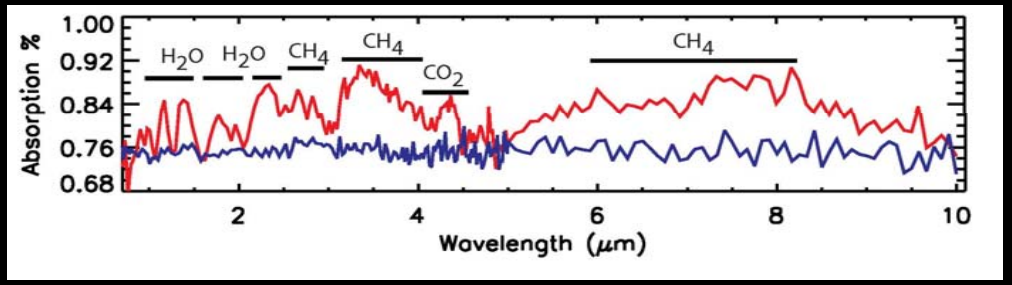
GAIA (ESA) finds >2,000 Jupiters @ <200 pc

CHEOPS (ESA) finds new transits & makes high precision light curves





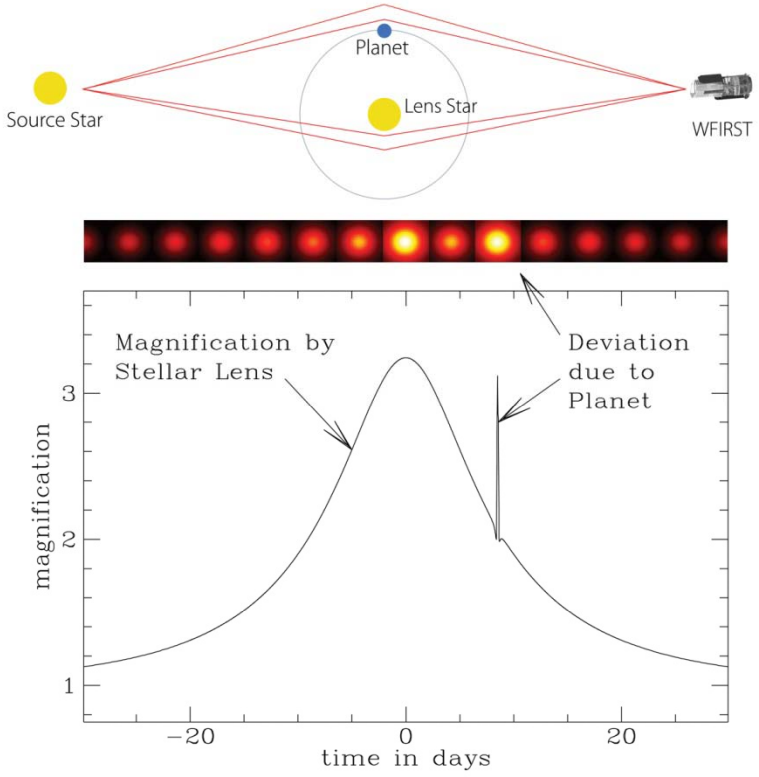
JWST (NASA/ESA/CSA) finds water on Super Earths & images young Saturns

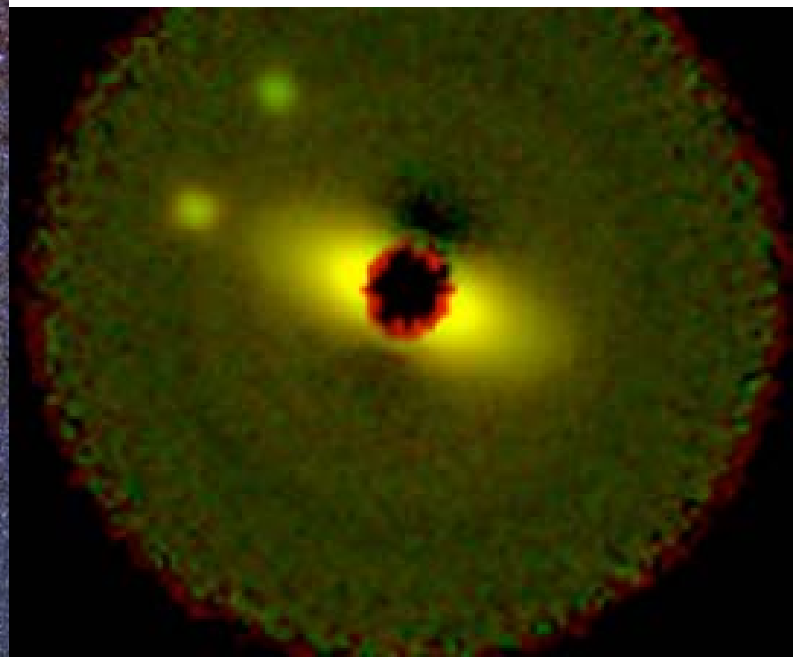


HR8799

2025-2035: Planetary System Architectures & First Nearby Earths

- Repurposed 2.4 m telescope (WFIRST) probes architecture beyond the "ice-line"
- ESA's Plato finds hundreds of Earths with accurate stellar ages
- NASA's 1.5 m coronagraphic telescope images Earthlike planet in HZ of α Cen B and gets spectra of dozens of gas giants
- ESA/Chinese astrometric mission finds **10 Habitable Zone Earths** orbiting 100 nearest bright stars





April 26, 2040: Life Finder Launched

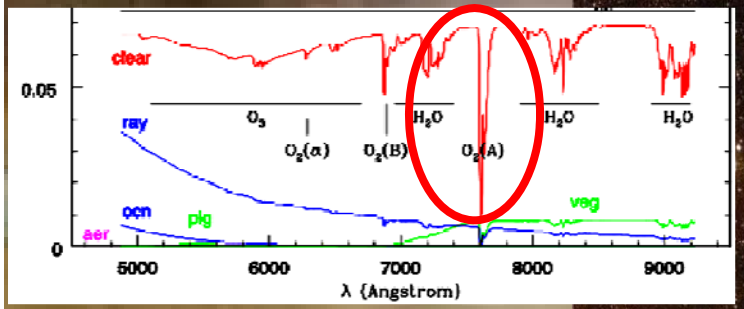
Human/Robotic tended facility at L2 enables giant telescopes

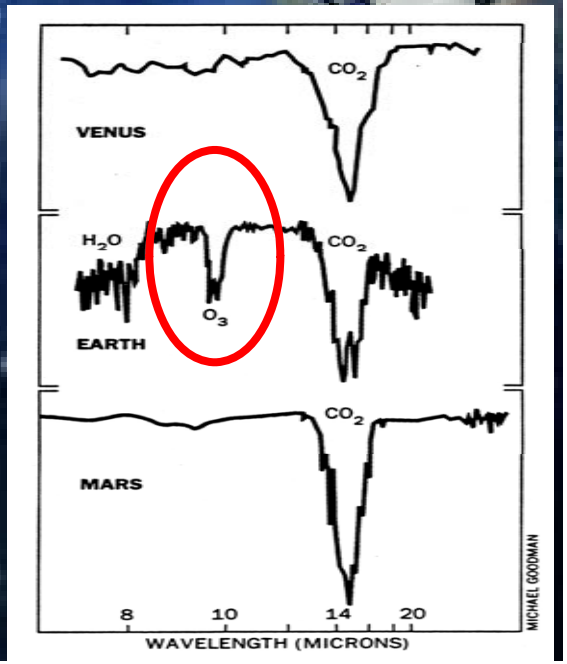
Oct 26, 2045: 3 of 10 Habitable planets show photosynthetic life

Darwin IR Interferometer

External Occulter

Visible Coronagraph





October 26, 2062: Complementary Searches Find Life in Our Own and Other Planetary Systems

Mars colonists find non-DNA life in 2 km deep aquifer

Jill Tarter's grand-daughter receives first SETI signal from a Life Finder target star